MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EPM4066 – ROBOTICS AND AUTOMATION
(ME)

6 MARCH 2017
2.30 p.m. – 4.30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 6 pages including cover page with 4 Questions only. DH-parameter procedures are included in Appendix.

2. Attempt **ALL** questions. All questions carry equal marks and thedistribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) What are the common classical robot configurations to find the joint angles of the main axes?

[4 marks]

(b) A manipulator with four degrees of freedom is shown in its home position in Fig. Q1. The first two joints and the fourth joint are revolute joints, while the third is a prismatic joint.

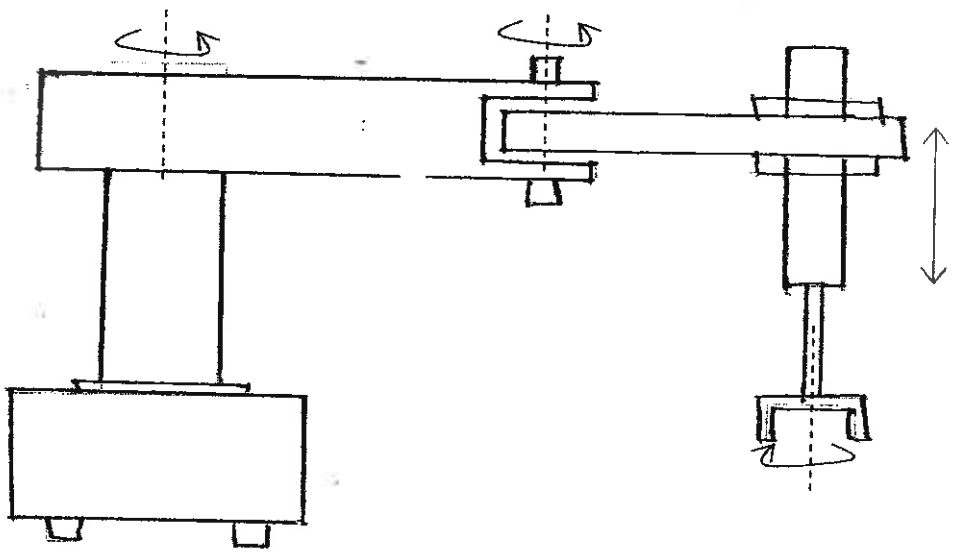

Fig. Q1

(i) Draw the link-coordinate diagram of this robot. Add all the necessary kinematic parameters and label them clearly based on Denavit-Hartenberg algorithm.

[8 marks]

(ii) Fill the kinematic parameters in the following table.

Axis	θ	d	a	α	Home
1					0
2					0
3					8
4					π/2

[6 marks]

(iii) Find the arm matrix $T_{base}^{tool}(q)$ at home position.

[7 marks]

Continued...

Question 2

(a) Consider the top view of a robotic workstation, with parts A and B, as shown in Fig.Q2. Suppose the centroid of part A has coordinates $[4, 9, 3]^T$ and the centroid of part B has coordinates $[8, 5, 4]^T$.

(i) Find the arm matrix value T_{base}^{pick} needed to pick up part A from above by grasping it in the middle of the long sides.

[3 marks]

(ii) Find the arm matrix value T_{base}^{pick} needed to pick up part B from above by grasping it in the middle of the long sides.

[4 marks]

(iii) Find the arm matrix value T_{base}^{place} needed to place part B on top of part A aligning the centroids and the major axes.

[3 marks]

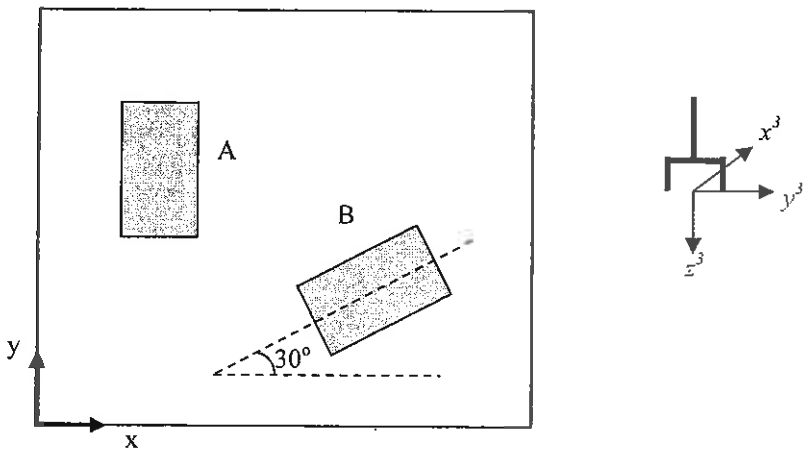

Fig. Q2

(b) The waist of a six-axis robot is to go from initial angle of 25° to an end position of 61° in 6 seconds. By using a third-order polynomial in joint-space, calculate the joint angle, velocity, and acceleration at the time 3 seconds. Assume the robot starts at rest and all joints stop at end point.

[10 marks]

(c) Define the Lift-off point and Place-point in a pick and place operation.

[5 marks]

Continued...

Question 3

(a) Briefly explain two types of joint space singularities.

[5 marks]

(b) Consider the link-coordinate diagram of a 3-axis articulated robot as shown in Fig.Q3. The arm matrix for this robot is given by:

$$T_{base}^{tool} = T_0^1 T_1^2 T_2^3$$

$$= \begin{bmatrix} C_1 & 0 & S_1 & 0 \\ S_1 & 0 & -C_1 & 0 \\ 0 & 1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C_2 & -S_2 & 0 & a_2C_2 \\ S_2 & C_2 & 0 & a_2S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C_3 & 0 & S_3 & 0 \\ S_3 & 0 & -C_3 & 0 \\ 0 & 1 & 0 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Find:

(i) The manipulator Jacobian matrix, $J(q)$.

[13 marks]

(ii) The joint torques and forces if an external force and moment vector, $F^{tool} = [0, 0, f_3, n_1, n_2, n_3]^T$ is applied at the tool tip.

[7 marks]

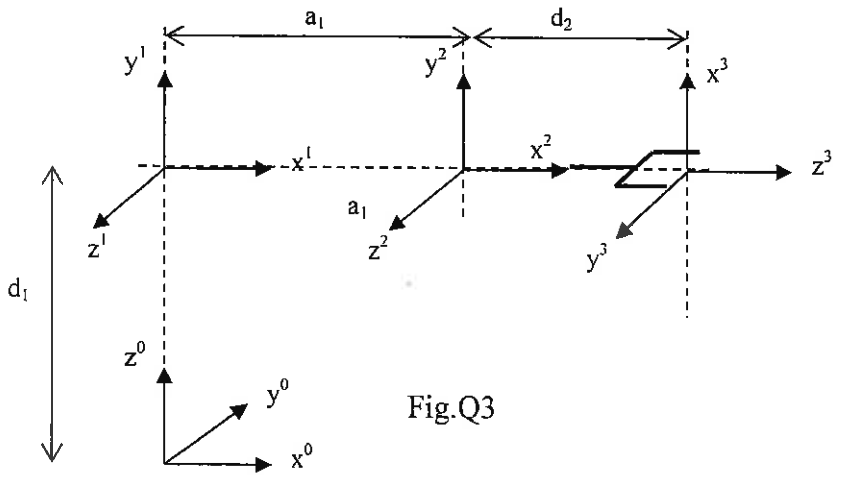

Fig.Q3

Continued...

Question 4

(a) The transfer mechanism functions are to move partially completed work parts or assemblies between adjacent stations and also to orient and locate the parts in the correct position for processing at each station. Explain briefly the three categories of transfer mechanism.

[6 marks]

(b) Plant layout refers to the arrangement of physical facilities in a production plant. Explain briefly the three principal types of plant layout.

[6 marks]

(c) A manufacturing company have a manufacturing section consists of 8 work centers, with all the works centers producing a same part. The section operates 7 shifts per week. The number of hours per shift averages 7. The average production rate is 20 units/h. Determine the production capacity of this manufacturing section.

[3 marks]

(d) The cost of the raw material for a certain part is RM 200. The part is processed through 25 processing steps in the plant and the manufacturing lead time is 20 weeks. The production time per processing step is 1 hour and the machine and labour rate is RM 20 / h. Inspection, material handling, and related costs average RM 20 per processing step by the time the part is finished. The interest rate 'i' used by the company is 20% and the storage rate,'s' is 15%. Determine the cost per part and the holding cost.

[10 marks]

Continued...

Appendix

Procedure to DH-Parameter

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set k=1.
3. Align z^k with the axis of joint k + 1.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k = k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
   and x^n with the normal vector of the tool. Set k =1.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute $\alpha_k$as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k = k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

End of Paper